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Publication number:

0 299 459  
A2

(12)

## EUROPEAN PATENT APPLICATION

(21) Application number: 88111227.0

(51) Int. Cl.<sup>4</sup>: B01D 13/01

(22) Date of filing: 13.07.88

(30) Priority: 13.07.87 JP 174451/87  
13.07.87 JP 174453/87  
26.02.88 JP 43449/88

(43) Date of publication of application:  
18.01.89 Bulletin 89/03

(34) Designated Contracting States:  
DE FR GB NL

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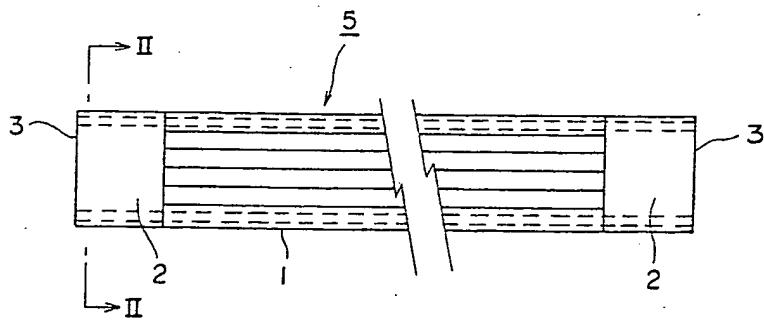
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(54) A filter element and a filter module comprising the same.

(57) A filter element comprising porous hollow fiber filter membranes arranged in a lengthwise direction and fusion-bonded together at one or both of their respective end portions to form a unified terminal block which has through-holes communicating with the hollows of the remaining unbonded portions of the membranes and having diameters substantially the same as the inner diameters of the membranes. The filter element not only is excellent in resistance to heat and chemicals, but also can realize an efficient filtration.

FIG. 1



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rendering the membrane unsuitable for practical use.

A porous hollow fiber filter membrane has a large number of pores that contain air. If a heated liquid is used as the heated fluid and is introduced into the interior of the hollow fiber filter membrane, the air in the pores is squeezed out as the membranes shrinks, thereby causing the hollow fiber filter membrane to have an irregular shape.

Further, porous hollow fiber filter membranes are inferior to tubes in mechanical strength. Therefore, when hollow fiber filter membranes are handled in the same manner as in the above method for bonding tubes, the hollow fiber filter membranes become bent or deformed, thereby causing the porous structures of the membranes to be non-uniform.

As mentioned above, the method of bonding tubes together which is disclosed in U.S. Patent No. 3,315,740 pertains to a technical field which is entirely different from the technical field to which the present invention belongs, i.e., the field of filter elements each comprising porous hollow fiber filter membranes.

In fact, in attempting to bond the end portions of hollow fiber filter membranes by fusion, various problems have been encountered. The term "fusion" used herein means to bring a material into a viscous state or a state where the solid phase and the liquid phase are in equilibrium.

A hollow fiber filter membrane is a porous body having a porosity of at least 30 %, as opposed to a tube and, hence, by the application of heat, a hollow fiber filter membrane shrinks considerably. Therefore, simple fusion of the end portions of hollow fiber filter membranes causes the inner diameters of the end portions of the hollow fiber filter membranes to drastically decrease with great disadvantages. For example,

when a hollow fiber filter membrane of an ethylene-tetrafluoroethylene copolymer resin, which has an inner diameter of 0.77 mm, an outer diameter of 1.24 mm and a porosity of 67 %, is heated in an oven maintained at 285 °C for 10 seconds, removed from the oven and cooled by air to room temperature, the inner diameter of the hollow fiber filter membrane decreases drastically to 0.30 mm, which is about 39 % of the inner diameter before the heat treatment. The outer diameter thereof also decreases drastically to 0.42 mm, which is about 34 % of the outer diameter before the heat treatment.

A filter element comprising hollow fiber filter membranes which have undergone such decrease in the inner diameters has severe drawbacks. For example, when carrying out filtration of a liquid containing a large amount of suspended solids by means of such a filter element, the hollow portions of the hollow fiber filter membranes are often clogged with the suspended solids because the inner diameters of the hollow fiber filter membranes are small, thereby causing the filtration to be inoperative. Further, when the filter element is used for the filtration of a highly viscous liquid, because the inner diameters of the hollow fiber filter membranes are small, there is caused a large pressure loss in the lengthwise direction. This leads to a decrease in the filtration pressure in the lengthwise direction, which causes lowering in filtering ability. Therefore, the use of this filter element for such filtration operations is disadvantageous from an economical point of view.

The drastic decrease in the outer diameter of a hollow fiber filter membrane by heat treatment also causes a problem in preparing a filter element from the membranes. Such decrease in the outer diameter makes it difficult to keep the end portions of hollow fiber filter membranes in contact with each other when heating the end portions of the membranes, thereby causing difficulties in effecting bonding of the end portions by fusion.

#### Summary Of The Invention

By extensive and intensive studies, the present inventors have succeeded in developing a completely novel filter element comprising a plurality of hollow fiber filter membranes bonded at one or both end portions thereof, which is free from the drawbacks inevitably accompanying the conventional filter elements of a hollow fiber filter membrane type, such as dissolution of the resins used as adhesives.

Accordingly, it is an object of the present invention to provide a filter element of a hollow fiber filter membrane type which is excellent in resistance to heat and chemicals.

It is another object of the present invention to provide a filter module accommodating therein the filter element of the above type.

The foregoing and other objects, features and advantages will be apparent to those skilled in the art from the following detailed description and claims taken in connection with the accompanying drawings.

membranes unbonded at their respective peripheries. In unified terminal blocks 2, the membranes are fusion-bonded at least at their respective peripheries.

In the present invention, the end portions of bundled hollow fiber filter membranes are fused at least at their respective peripheries and then cooled to provide fusion-bonding between the membranes. In effecting the fusion of the membranes, a powder of thermoplastic resin may be interposed between the membranes. Therefore, with respect to the end portions of hollow fiber filter membranes which are fusion-bonded, the boundaries between the peripheries of the hollow fiber filter membranes or between the peripheries of the hollow fiber filter membranes and the thermoplastic resin medium are no longer present as shown in Fig. 6. Further, it is noted that in the process of fusion, the pore structures of the membranes disappear at the fused portion of the membranes and, therefore, the thickness of the membranes decreases at the fused portion. By contrast, in a conventional filter element in which hollow fiber filter membranes are bonded together by means of an adhesive, there are recognized boundaries between the peripheries of the hollow fiber filter membranes and the adhesive as shown in Fig. 7. Further, with respect to the conventional filter element, it is noted that the original pore structures of the membranes are maintained in its entirety at the bonded portion of the membranes and, therefore, there is no decrease in the thickness of the membranes at the bonded portion.

Unified terminal blocks 2 have through-holes which communicate with the hollows of the unbonded portions of the membranes, and have openings 4 at end surfaces 3 of filter element 5. The diameters of the through-holes are substantially the same as those of the hollows of the unbonded portions of the membranes which hollows communicate with the through-holes. In other words, the end portions of membranes 1 are fusion-bonded at least at their respective peripheries so that the diameter of the resultant through-hole formed in the end portion of filter element 5 by fusion of the membranes is the same as the inner diameter of the hollow fiber membrane as measured before the membrane is subjected to the fusion-bonding. The unbonded portions of hollow fiber filter membranes 1 still keep the original filtering abilities of the hollow fiber filter membranes.

In the filter element of the present invention, the through-holes of the unified terminal block generally have circular or polygonal cross-sections. It is preferred from the viewpoint of a smooth flow of a liquid through the filter element that the through-holes of the unified terminal block have circular cross-sections.

Further, in the present invention, the inner walls of the through-holes in the unified terminal block may have porous structures which are derived from the porous structures of the hollow fiber filter membranes.

The diameter of a through-hole in the unified terminal block can be determined by cutting the unified terminal block in the direction perpendicular to the lengthwise direction of the hollow fiber filter membranes to obtain a cross-section of the through-hole and measuring the diameter of the cross-section of the hole. When the cross-section of the hole is polygonal, the diameter of the cross-section is defined as the diameter of the circle inscribed in the polygon.

In unified terminal blocks 2, the end portions of membranes 1 may be fusion-bonded either directly or through a thermoplastic resin medium. When the end portions of membranes 1 are fusion-bonded through a thermoplastic resin medium, the thermoplastic resin medium is made of either a resin of the same type as that used for the hollow fiber filter membranes or a resin which is of a type different from the type of the resin used for the hollow fiber filter membranes and which is compatible with the resin used for the membranes and has a softening point preferably 0.5 to 1.5 times, more preferably 0.8 to 1.2 times, as high as the softening point (°C) of the thermoplastic resin used for the hollow fiber filter membranes. The term "softening point" as used herein is intended to mean the melting point if the resin is of a crystallizable type and to mean the glass transition point if the resin is of a non-crystallizable type. Resins suitable for the thermoplastic resin medium include, for example, FEP (melting point: 250-295 °C), PFA (melting point: 302-310 °C), ETFE (melting point: 270 °C), polyethylene (melting point: 108-135 °C), polypropylene (melting point: 160-165 °C), polyamide (melting point: 215-255 °C) and polysulfone (glass transition point: 190 °C).

If the resin for hollow fiber filter membranes 1 is different in softening point from the resin for the thermoplastic resin medium, it is necessary that the temperature needed to melt one resin having a higher softening point be lower than the decomposition temperature of the other resin having a lower softening point. The resin for membranes 1 and the resin for the medium may preferably be of substantially the same softening point, more preferably of the same type.

In Fig. 3, there is shown a partly cut-away diagrammatic side view of another form of filter element according to the present invention, in which the hollows of the uppermost and lowermost membranes and the uppermost and lowermost through-holes of the unified terminal blocks are shown by broken lines. Fig. 4 shows a diagrammatic cross-sectional view taken along the line IV-IV in Fig. 3. Filter element 5 which is shown in Figs. 3 and 4 is substantially the same as the filter element shown in Figs. 1 and 2 except that the

possible within the respective ranges in which the hollow fiber filter membranes are not damaged.

After the extraction of the filler, the sealed portions of the membranes are cut off to obtain a filter element comprising hollow fiber filter membranes having one or both end portions directly fusion-bonded.

5 (2) A filter element in which one or both end portions of the membranes are directly fusion-bonded can also be produced by the following method:

One end portion of hollow fiber filter membranes is dipped in a sealing medium consisting of about 2 parts by weight of calcium sulfate, about 4 parts by weight of calcium carbonate and about 3 parts by weight of water so that the sealing medium fills the hollows of at least the portions of the membranes which portions are to be fusion-bonded. The hollow fiber filter membranes may be either those containing no filler 10 or those containing an inorganic filler, which are prepared in the same manner as in method (1). In the case of the latter, the filler is extracted from the peripheries of the end portions of the membranes in the same manner as in method (1).

After the sealing medium has been dried, the hollow fiber filter membranes are arranged in a lengthwise direction to form a bundle so that the sealed end portions are disposed at one end portion of the bundle.

15 Then, the sealed end portions of the membranes are heated in substantially the same manner as in method (1) to form a unified terminal block. If desired, a unified terminal block may also be provided at the other end of the bundle in the same manner as mentioned above. Subsequently, if the hollow fiber filter membranes used are those containing an inorganic filler, the filler is completely extracted from the entire wall of each membrane in the same manner as in method (1).

20 Finally, the sealing medium contained in the hollows of the end portions of the membranes is extracted with 35 % hydrochloric acid to obtain a filter element.

(3) A filter element in which one or both end portions of the membranes are fusion-bonded through a thermoplastic resin medium interposed between the peripheries of the end portions of the membranes can be produced, for example, by the following method:

25 Hollow fiber filter membranes which are substantially equal in length and containing a fine-particle inorganic filler are prepared in the same manner as described in (1) above. Then, the filler is extracted from only the peripheries of the end portions of the membranes in the same manner as described in (1) above.

After the extraction, a powdery thermoplastic resin is applied to the peripheries of the end portions of the membranes.

30 The powdery thermoplastic resin is a resin which may be the same as or different from the resin used for the hollow fiber filter membranes and which is compatible with the resin used for the membranes and has a softening point preferably 0.5 to 1.5 times, more preferably 0.8 to 1.2 times, as high as the softening point (°C) of the thermoplastic resin used for the hollow fiber filter membranes. It is preferred that the powdery thermoplastic resin have the same softening point as that of the resin used for the membranes. It 35 is most preferred that the powdery thermoplastic resin be of the same type as the resin used for the membranes.

The powdery resin can be applied to the peripheries of the end portions of the membranes, for example, by first dipping the end portions in a liquid to wet the surface of the peripheries of the end portions of the membranes and then either putting the end portions wetted with the liquid in the powdery 40 resin or spraying or spreading the powdery resin to the wetted end portions.

As the liquid in which the end portions of the membranes are dipped, there may be employed any of inorganic compounds, organic compounds and mixtures thereof as long as they are not corrosive to the hollow fiber filter membranes. Suitable examples of such liquids include water, polyethylene glycol, polypropylene glycol, ethanol and dihydroxyphthalate. It is not preferred to use N,N-dimethylacetamide or 45 N-methylpyrrolidone for hollow fiber filter membranes of polysulfone, because it decomposes the membranes.

In the operation for dipping the end portions in a liquid, the end portions of the membranes are maintained in the liquid for 0.2 sec or longer. The dipping operation may be carried out in such a manner that each membrane is dipped in the liquid separately or that a plurality of membranes are arranged into a 50 bundle and dipped in the liquid collectively. When a plurality of membranes are collectively dipped in the liquid, the peripheries of the end portions of the membranes which are disposed in the inner portion of the bundle are often not readily wetted by the liquid because of the viscosity of the liquid. In such a case, the liquid may be subjected to ultrasonic treatment during the immersion of the end portions of the membranes in the liquid, thereby enabling the liquid to be attached to the peripheries of the end portions of all the 55 membranes including those disposed in the inner portion of the bundle. In this instance, the ultrasonic treatment can be performed more effectively by increasing the temperature of the liquid so as to lower the viscosity of the liquid.

The powdery thermoplastic resin may be a mixture of powdery resins having different softening points.

end portion of the bundle is placed within a sleeve made of the same resin as used for the thermoplastic resin medium. Around a portion of the bundle which is outside the sleeve is wound a tape. The sleeve and the end portion of the bundle within the sleeve are heated while feeding an inert gas at room temperature into the hollows of the membranes from the openings at the other ends of the membranes.

5 If desired, prior to the heat treatment, the sleeve and a portion of the bundle within the sleeve may be placed in a powdery thermoplastic resin which is mentioned in method (2) while subjecting the powdery resin to ultrasonic treatment, to thereby fill the interstices between the peripheries of the end portions of the membranes and between the internal surface of the sleeve and the peripheries of the end portions of the membranes with the powdery resin.

10 By the above-mentioned heat treatment, the end portions of the membranes are fluid-tightly fusion-bonded together and, at the same time, the end portions of the membranes disposed in the periphery of the bundle are fluid-tightly fusion-bonded to the internal surface of the sleeve, thereby forming a unified terminal block having thereover an outer resin layer fusion-bonded thereto. After the heat treatment, the outermost end portion of the unified terminal block having thereover the resin layer fusion-bonded thereto  
15 are cut off to expose openings at the end surface of the unified terminal block. If desired, a unified terminal block having openings and having thereover an outer resin layer fusion-bonded thereto may also be provided at the other end portion of the bundle of the membranes in substantially the same manner as mentioned above.

Finally, after the tape wound around the bundle is removed, the hollow fiber filter membranes are  
20 subjected to complete extraction of the filler in substantially the same manner as in method (1) to thereby obtain a filter element comprising hollow fiber filter membranes having one or both end portions fluid-tightly fusion-bonded to form a unified thermal block having an outer resin layer fusion-bonded thereto.

(6) Alternatively, a filter element in which the unified terminal block has an outer resin layer fusion-bonded thereto may also be prepared as follows.

25 Hollows of one end portion of hollow fiber filter membranes is dipped in a sealing medium consisting of about 2 parts by weight of calcium sulfate, about 4 parts by weight of calcium carbonate and about 3 parts by weight of water so that the sealing medium fills the hollows of at least the portions of the membranes which portions are to be fusion-bonded. The hollow fiber filter membranes may be either those containing no filler at least at their respective end portions or those containing an inorganic filler which are prepared in  
30 the same manner as in method (1). In the case of the latter, the filler is extracted from the peripheries of the end portions of the membranes in the same manner as in method (1).

After the sealing medium has been dried, the hollow fiber filter membranes are arranged in a lengthwise direction to form a bundle so that the sealed end portions are disposed at one end portion of the bundle. The end portion of the bundle is dipped in the liquid as mentioned in (3) above and placed in the powdery  
35 thermoplastic resin as mentioned in (3) above while subjecting the powdery resin to ultrasonic treatment, to thereby fill the interstices between the peripheries of the end portions of the membranes with the powdery resin. The end portion of the bundle is then inserted into a portable compression mold through an opening of the mold, the opening having the same diameter as that of the end portion of the bundle, and the remaining space within the mold is filled with the powdery thermoplastic resin. The portable compression  
40 mold containing the end portion of the bundle and the powdery resin are placed in an oven and heated while compressing the powdery resin to thereby form a unified terminal block having thereover an outer resin layer fusion-bonded thereto. If desired, a unified terminal block having thereover an outer resin layer may be provided also at the other end portion of the bundle of the membranes in substantially the same manner as mentioned above. Subsequently, if the hollow fiber filter membranes used are those containing  
45 an inorganic filler, the filler is completely extracted from the entire wall of each membrane in substantially the same manner as in method (1).

Finally, the sealing medium contained in the hollows of the end portions of the membranes is extracted with 35 % hydrochloric acid to obtain a filter element.

By any of the above described methods (1) to (6), the end portions of the membranes are fusion-bonded at their respective peripheries without substantial decrease in the inner diameters of the end portions of the membranes. Therefore, a filter element which enjoys the original filtering abilities of the hollow fiber filter membranes used can be obtained.

The through-holes of the unified terminal block of the filter element of the present invention preferably have circular cross-sections as mentioned above. The filter elements having such through-holes in the  
55 unified terminal block can be produced, for example, by methods (2) and (6) mentioned above.

In the filter element of the present invention, the inner walls of the through-holes in the unified terminal block may have porous structures which are derived from the porous structures of the hollow fiber filter membranes, as mentioned above. The filter elements having a uniform terminal block of such characteris-

have free ends, the openings of which are sealed, for example, by fusion.

In the filter module of the present invention, the filter element accommodated therein is preferably of the type in which the end portion of the hollow fiber filter membranes is fusion-bonded through a thermoplastic resin medium.

5 Further, it is noted that an assembly which is prepared simply by fluid-tightly connecting suitable tubes to both end portions of a filter element of the type shown in Fig. 1 may be used in filtration. In the assembly thus constructed, the tubes connected to both end portions of the filter element can serve as chambers each having an opening. The chambers serve for pooling a liquid.

The present invention will now be described in more detail with reference to the following Examples,  
10 which should not be construed as limiting the scope of the present invention.

#### Example 1

15 14.4 % by volume of a fine powder of silicic acid (Aerosil R-972 manufactured by NIPPON AEROSIL, Japan) and 58.9 % by volume of a chlorotrifluoro-ethylene oligomer (Difloil #100 manufactured by Daikin Industries, Ltd., Japan) were mixed in a Henschel mixer. To the resultant mixture was added 26.7 % by volume of an ethylene-tetrafluoroethylene copolymer (Neoflon ETFE manufactured by Daikin Industries, Ltd., Japan) and mixed in the Henschel mixer.

20 The resultant mixture was extruded by a 30 mmØ diameter twin-screw extruder at 260 °C to thereby obtain pellets. The pellets were molded at 250 °C by means of a twin-screw extruder provided with a spinneret having an annular orifice, thereby obtaining an extrudate in the form of hollow fibers. The hollow fibers were immersed in 1,1,1-trichloroethane at 50 °C for 1 hour to extract the chlorotrifluoroethylene oligomer, and dried to obtain hollow fiber filter membranes. Subsequently, the thus obtained hollow fiber  
25 filter membranes were subjected to annealing at 200 °C for 1 hour to obtain annealed hollow fiber filter membranes. The annealed hollow fiber filter membranes had an inner diameter of 0.77 mm, an outer diameter of 1.24 mm, an average pore diameter of 0.21 µm, a porosity of 67 % and a melting point of about 270 °C.

20 The end portion of the above-obtained hollow fiber filter membranes was dipped in a mixture of water and gypsum and then dried, thereby sealing the openings of the end portions with the gypsum filled in each of the hollows of the end portions of 8 mm in length from the terminal of each hollow fiber filter membrane. The sealed end portions of the hollow fiber filter membranes were immersed in an aqueous 5 % NaOH solution at 25 °C for 65 min while subjecting the solution to ultrasonic treatment by means of an ultrasonic cleaner (MODEL B-2200 manufactured and sold by BRANSONIC CLEANING EQUIPMENT COMPANY, U.S.A.) silicic acid powder from only the peripheries of the sealed end portions of the hollow fiber filter membranes.

35 Ten of the thus-obtained hollow fiber filter membranes were arranged in a lengthwise direction to form a bundle so that the sealed end portions were disposed at one end portion of the bundle, and the end portion of the bundle was bound by a tape (NITOFLON PIPESEAL manufactured and sold by NITTO ELECTRIC INDUSTRIAL CO., LTD., Japan). The tape-bound end portion was put in an oven adjusted to 285 °C and maintained therein for about 115 sec, and then taken out from the oven and cooled, to thereby obtain a bundle of hollow fiber filter membranes having one of their respective end portions fusion-bonded together, the end portions being 30 mm in length from the respective terminals of the membranes, thereby forming a unified terminal block.

40 The above-described procedure was repeated with respect to the other end portions of the hollow fiber filter membranes. Subsequently, the tape wound around the end portions of the bundle was removed and the entire bundle of 10 membranes was immersed in an aqueous 40 % NaOH solution at 70 °C for 1 hour, thereby substantially removing the silicic acid powder from all portions of the membranes.

45 The outermost end portions of both the unified terminal blocks were cut off by a knife so that openings were exposed in the end surfaces of the unified terminal blocks, thereby obtaining a filter element comprising a plurality of hollow fiber filter membranes. The diameter of the opening in the end surfaces of the unified terminal blocks is shown in Table 1.

50 Both the unified terminal blocks had through-holes communicating with the openings in the respective end surfaces of the terminal blocks and with the hollows of the unbonded portions of the membranes. The through-holes had circular cross-sections, except for the peripheral through-holes having triangular cross-sections. The inner walls of the through-holes had porous structures.

is shown in Table 1.

Both the unified terminal blocks had through-holes communicating with the openings in the respective end surfaces of the terminal blocks and with the hollows of the unbonded portions of the membranes. All of the through-holes had circular cross-sections. The inner walls of the through-holes had porous structures.

5

#### Example 4

Annealed hollow fiber filter membranes having the same characteristics as described in Example 1 were 10 prepared in the same manner as in Example 1.

With respect to the thus obtained hollow fiber filter membranes, sealing of one end portions of the fibers and removal of the silicic acid powder from only the peripheries of the sealed end portions of the membranes were conducted in the same manner as in Example 1.

Ten of the thus-obtained hollow fiber filter membranes were arranged in a lengthwise direction to form a 15 bundle so that the sealed end portions were disposed at one end portion of the bundle and the end portion of the bundle was inserted into a cylindrical sleeve which is made of the same material as that of the hollow fiber filter membranes and which has an inner diameter such as to closely cover the bundle. The portion of the bundle which was outside the sleeve was bound with a seal tape (manufactured by Nippon Balka Co., Japan). The sleeve and the end portion of the bundle within the sleeve were dipped in water and then put 20 into a fine powder (ASTM 100 mesh pass) of the same material as that of the hollow fiber filter membranes and maintained therein for 30 sec while subjecting the powder to ultrasonic treatment. Subsequently, the sleeve and the end portion of the bundle were put in an oven adjusted to 285 °C and maintained therein for 5 min while nitrogen gas at about 25 °C was fed into the hollows of the membranes from their respective 25 openings at the unsealed ends of the membranes at a rate of from 20 ml/min to 4,000 ml/min, and then, pulled out of the oven and allowed to stand for cooling, thereby forming a unified terminal block of 30 mm in length which block had thereover an outer resin layer fusion-bonded thereto.

The outermost end portion of the unified terminal block having thereover an outer resin layer was cut off by a diamond cutter, thereby exposing openings in the end surface of the unified terminal block.

The same procedure as described above was repeated with respect to the other end portions of the 30 hollow fiber filter membranes. Then, after removing the tape wound around the bundle, the entire bundle of 10 hollow fiber filter membranes was immersed in a 40 % aqueous NaOH solution at 70 °C for 1 hour, thereby substantially removing the silicic acid powder from all portions of the membranes. Thus, there was obtained a filter element having unified terminal blocks of 30 mm in length, which blocks each had an outer resin layer fusion-bonded thereto, as schematically shown in Fig. 3. The diameter of the opening in the end 35 surface of each of the unified terminal blocks is shown in Table 1.

Both the unified terminal blocks had through-holes communicating with the openings in the respective end surfaces of both the blocks and with the hollows of the unbonded portions of the membranes. The through-holes had circular cross-sections except for the peripheral through-holes having triangular cross-sections. The inner walls of the through-holes had porous structures.

40

#### Example 5

Annealed hollow fiber filter membranes having the same characteristics as described in Example 1 were 45 prepared in the same manner as in Example 1.

With respect to the thus obtained hollow fiber filter membranes, one end portions of them were immersed in an aqueous 25 % NaOH solution at 70 °C for 6 hours, the end portions being 90 mm in length from the respective terminals of the membranes, thereby completely removing the silicic acid powder from the end portions. The end portions of the membranes were washed with water for 12 hours. Separately, 50 about 20 g of calcium carbonate and about 8 g of calcium sulfate were kneaded with about 10 ml of water to prepare a sealant. The sealant was packed in each of the hollows of the above-treated end portions of the membranes from the opening, the end portions being 85 mm in length from the respective terminals of the membranes, thereby sealing the end portions of the membranes.

Ten of the thus obtained hollow fiber filter membranes were arranged in a lengthwise direction to form a 55 bundle in which the sealed end portions were disposed at one end portion of the bundle and the interstices between the peripheries of the end portions of the membranes were filled with a fine powder (ASTM 100 mesh pass) of the same resin as that of the membranes, the end portions being 50 mm in length from the respective terminals of the membranes. Then, the end portion of the bundle was bound by a Teflon seal

Table 1

	Diameter of the openings in the end surface of the unified terminal block of the filter element
Example 1	0.70 mm
Example 2	0.72 mm
Example 3	0.71 mm
Example 4	0.73 mm
Comparative Example	0.77 mm

## 15 Example 7

The filter elements obtained in Examples 1 to 4 and the Comparative Example were each separately immersed in a 35 % hydrogen peroxide solution. Each solution was replaced with a fresh solution every 24 hours and the solution replaced was subjected to measurement of the TOC content using TOC-500 (manufactured and sold by Shimadzu Seisakusho Ltd., Japan). The results are shown in Table 2.

Table 2

	Content of TOC (ppm)		
	1st solution	3rd solution	5th solution
Example 1	1.2	0.4	0.1
Example 2	1.5	0.6	0.1
Example 3	1.2	0.4	0.1
Example 4	1.4	0.6	0.1
Comparative Example	12.3	3.4	1.3

Note: The values in Table 2 were obtained by deducting the TOC value of the 35 % hydrogen peroxide from the measured TOC values.

40

## Claims

1. A filter element comprising a plurality of porous hollow fiber filter membranes of a thermoplastic resin which are substantially equal in length and arranged in a lengthwise direction, said membranes each having a porosity of from 30 to 90 %, at least one of the end portions of said membranes being fusion-bonded at least at their respective peripheries directly or through a thermoplastic resin medium to form a unified terminal block in which the end portions of said membranes are fluid-tightly bonded together in a fused fashion, leaving the remaining portions of said membranes unbonded at their respective peripheries, said unified terminal block having through-holes communicating with the hollows of the unbonded portions of said membranes, said through-holes having diameters substantially the same as those of the hollows of the unbonded portions of said membranes which hollows communicate with said through-holes.
2. The filter element according to claim 1, wherein said end portions of the membranes are directly fusion-bonded.

FIG. 1

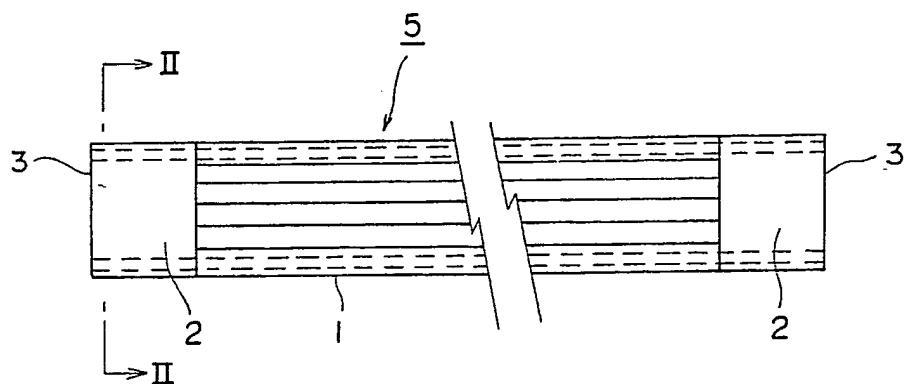


FIG. 2

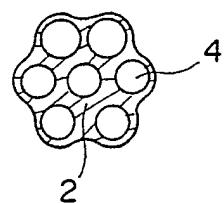


FIG. 3

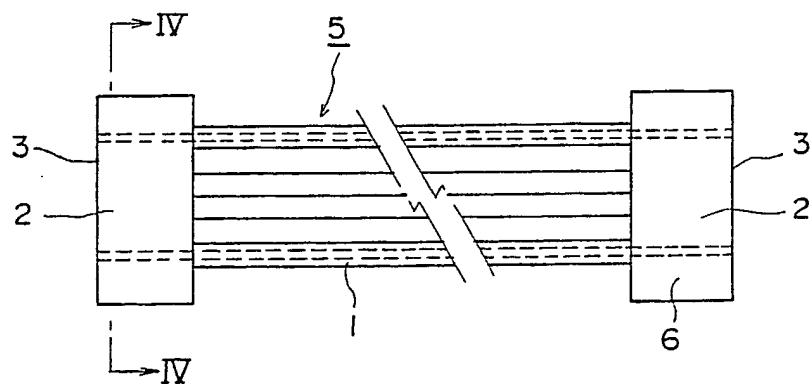
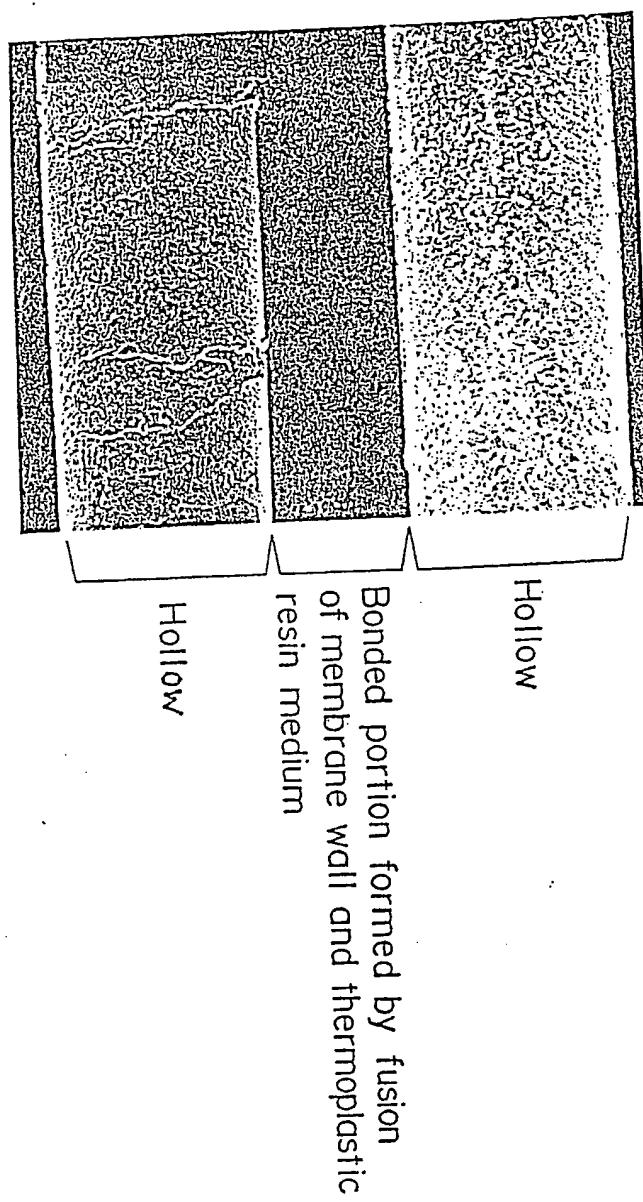


FIG. 6





Europäisches Patentamt

European Patent Office

Office européen des brevets

⑪ Publication number:

0 299 459

A3

⑫

## EUROPEAN PATENT APPLICATION

⑬ Application number: 88111227.0

⑮ Int. Cl.4: B 01 D 13/01

⑭ Date of filing: 13.07.88

⑩ Priority: 13.07.87 JP 174451/87  
13.07.87 JP 174453/87  
26.02.88 JP 43449/88

⑪ Date of publication of application:  
18.01.89 Bulletin 89/03

⑫ Designated Contracting States: DE FR GB NL

⑬ Date of deferred publication of search report:  
22.02.89 Bulletin 89/08

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⑲ A filter element and a filter module comprising the same.

⑳ A filter element comprising porous hollow fiber filter membranes arranged in a lengthwise direction and fusion-bonded together at one or both of their respective end portions to form a unified terminal block which has through-holes communicating with the hollows of the remaining unbonded portions of the membranes and having diameters substantially the same as the inner diameters of the membranes. The filter element not only is excellent in resistance to heat and chemicals, but also can realize an efficient filtration.

FIG. 1

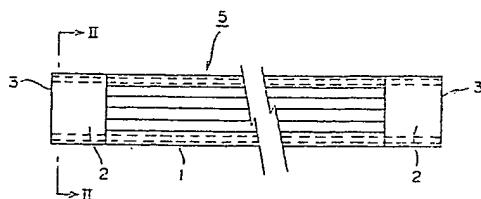


FIG. 2

